A Summary of Current Program and
Preliminary Report of Progress

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RESEARCH
on
NAVAL STORES and MAPLE SAP AND SIRUP PROCESSING AND PRODUCTS
and
REVEGETATION and WEED AND BRUSH CONTROL ON FOREST AND RELATED RANGES

of the Agricultural Research Service,
United States Department of Agriculture
and cooperating
State Agricultural Experiment Stations

This progress report of U.S.D.A. and cooperative research is primarily a tool for use of scientists and administrators in program coordination, development and evaluation; and for use of advisory committees in program review and development of recommendations for future research programs.

The summaries of progress on U.S.D.A. and cooperative research include some tentative results that have not been tested sufficiently to justify general release. Such findings, when adequately confirmed will be released promptly through established channels. Because of this, the report is not intended for publication and should not be referred to in literature citations. Copies are distributed only to members of Department staff, advisory committee members and others having an interest in the development of public agricultural research programs.

This report also includes a list of publications reporting results of U.S.D.A. and cooperative research issued during the past year. Current agricultural research findings are also published in the monthly U.S.D.A. publication Agricultural Research.

UNITED STATES DEPARTMENT OF AGRICULTURE
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Copies of this report may be obtained from David J. Ward, Executive Secretary, Forestry Research Advisory Committee, U. S. Department of Agriculture, Washington, D. C. 20250

INTRODUCTION

This is ONE part of a TWO part report of cooperative U.S.D.A. research relating to all aspects of forested land and related ranges.

This part of the Forestry report deals with research conducted by certain divisions in the Agricultural Research Service; the other and larger part includes discussions of all Forest Service research. Limited information about State Agricultural Experiment Station research is included with each area. Cooperative work with the U.S.D.A. is included in discussions of highlights of research progress.

Agricultural Research Service (ARS) investigations with naval stores and maple sap and sirup deal with the development of new and improved products and processing technology and the acquisition of basic knowledge about chemical composition and chemical and physical properties of these products. During the past fiscal year, about 23 professional man-years were devoted to these areas of utilization research.

The portion of ARS range improvement research covered in this report deals with problems associated with revegetation and fertilization of forest ranges. Methods of seeding, establishing, and managing ranges for domestic livestock are studied together with evaluations of the suitability of grass species or varieties for use as range plants. ARS investigations in this area involved about 3 professional man-years in fiscal year 1964.

Research on the control of weeds and brush on forest and related grazing lands is a part of ARS weed control studies with forage and range plants. In fiscal year 1964 about 24 professional man-years were devoted to the area of work covered in this report.

The above estimates of scientific effort do not include any part of programs of a basic research that will produce results of value to many problem areas.

Successful applications of results of agricultural research have been numerous and impressive. A few examples from the research areas covered in this part of the report are presented here.

> Naval Stores Products in Synthetic Rubber. Fundamental and applied research on new and improved products from pine gum has resulted in the use of substantial quantities of naval stores derivatives in the production of synthetic rubber. Virtually all of the synthetic rubber for use in automobile tires is made

by a process which uses paramenthane hydroperoxide as the catalyst and a disproportioned rosin soap as the emulsifier. The hydroperoxide is produced from turpentine or related terpenes and current consumption of terpenes for this use is estimated at 5 million pounds per year. The soap is produced from rosin by a catalytic process and consumes about 60 million pounds of rosin per year.

Research at the Naval Stores Laboratory on the catalytic dehydrogenation of rosin, the removal of polymerization inhibitors from the product, and on the production and use of the hydroperoxide was instrumental in the creation of these new markets for naval stores products. Research in this area is continuing and other useful products have been produced recently from white pine gum as well as from its various components.

Maple Sirup. The effects of 14 years of research on improved methods of sap harvesting and processing has caused maple sirup production to be changed from one of gradual decline to one of sharp increase. The 1964 crop, a normal one, shows an increase in U. S. production of 17% over the 5 year (1958-1962) average and a 38% increase over the 1963 crop. This increase reflects the pronounced increase in number of trees tapped and of the new acreage being brought into sirup production. These effects of research have also been accompanied by a steady increase in sirup quality, with more than 90% of the 1964 crop in the top grade with a corresponding increase in dollar value.

Also, as a result of the combined efforts of USDA scientists and industry, 1964 marked the first utilization of vegetable processing plant facilities for the evaporation of maple sap to sirup; two of these were in New York. This development utilizes these plants during a period when they are normally shut down and has and will bring about the tapping of vast numbers of additional trees. These plants, obtaining their sap from depressed areas, are contributing much toward better land use.

Forage Grasses Successful in Vegetating Southern California Fuel Breaks. Chaparral sites in southern California have supported destructive fires, and left large areas exposed to erosion by water. Studies in the Angeles, San Bernardino and Cleveland National Forests, at elevations of 1,600 to 5,600 feet have demonstrated the superiority of forage grasses as cover for fuel breaks. Of many grasses tested, pubescent

wheatgrass A-1488, and tall wheatgrass A-1876 were most successful. Good results were also obtained from other strains of pubescent wheatgrass and with intermediate wheatgrass, Hardinggrass, nodding needlegrass, Lomas grass (a selection of blue wildrye), and Sherman big bluegrass. Tall wheatgrass, varieties Alkar and S-64, were poor.

I. NAVAL STORES PROCESSING AND PRODUCTS
Southern Utilization Research and Development Division

Problem. More uses for turpentine, rosin and pine gum need to be developed through research to provide new industrial markets for current and anticipated production of gum naval stores. These gum naval stores products face serious competition for markets from research-developed products, especially those from the chemical and petroleum industries. As an illustration, turpentine has lost substantially all of its industrial solvent market to low-cost petroleum based solvents. New fundamental information about the chemistry, composition and properties of pine gum, rosin and turpentine is needed to fully exploit their unique characteristics in the production of new and improved industrial products having utility as industrial chemicals, polymers, plastics, elastomers, resins, plasticizers, surface coatings, textile finishes, odorants, insecticides and herbicides. There is also a serious need to improve existing processes and develop new processing technology for the industry.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program at Olustee, Florida, involving organic chemists and a chemical engineer engaged in both basic and applied research to discover and develop new and improved uses for pine gum and its products. In research to develop new and improved industrial products from pine gum, rosin, turpentine, or their components, conversion of the resin acids derived from gum rosin and pine gum to new polyfunctional products by reaction with suitable chemicals is under investigation to develop intermediates for production of resins, plastics, plasticizers, and other products. Another research approach involves the condensation of the unsaturated (olefinic) materials present in pine gum with certain reactive chemicals (dienophiles) to produce industrially useful chemicals. Research is also being conducted to develop uses for photosensitized oxidized pine gum and components, primarily in the fields of plastics and rubber. Other research includes investigations to convert turpentine and rosin into polymerizable products suitable for making new polymers, plastics, and resin; to prepare chemical intermediates and modified rosin compositions by hypochlorite reaction of rosin and resin acids; to convert rosin, resin acids, and resin acid derivatives to polyfunctional compounds useful in plastics, resins, and surface coatings by formaldehyde addition and subsequent reactions; and to produce reactive chemical intermediates from turpentine and terpenes derived from it by reaction with inexpensive dienophiles. The Pulp Chemicals Association supports a Fellowship at the Naval Stores Laboratory for the purpose of conducting research to develop a suitable method for determining rosin and rosin derivatives in protective coatings, a

necessity if rosin is to be allowed in certain types of these coatings from which it is now excluded. Informal cooperation is maintained with other agencies and industrial firms in connection with the naval stores research program. The U. S. Forest Service cooperates by supplying selected samples of pine gum.

Additional research on new and improved industrial products is in progress under contract at the University of Cincinnati, Cincinnati, Ohio, on the application of the oxo and related reactions to terpenes and resin acids to produce new, useful alcohols, aldehydes, and/or acids, and the characterization of the products thus obtained; at Cornell University, Ithaca, New York, on the synthesis of terpene alcohols and glycols for use in the production of new and useful terpene derived polymers; and at the University of Florida, Gainesville, Florida, on the development of a practical process for the conversion of α-pinene to dimers in good yields, and the conversion of these dimers to useful, reactive derivatives.

Research in the field of chemical composition and physical properties is in progress under a grant of P.L. 480 funds to the Juan de la Cierva School of Technical Investigations, Barcelona, Spain, for development of new or improved methods of preparing selected terpene alcohols for use as standards, to obtain basic information on the composition and properties of products made from pine gum (project duration - 3 yrs.).

The Federal in-house scientific research effort in this area totals 15.0 professional man-years. All of this effort is on new and improved industrial products. The contract research involves an additional 2.7 man-years on new and improved industrial products. P.L. 480 research involves 1 grant for research in the field of chemical composition and physical properties.

The following line of work was terminated during the year: (1) Development of process for isolation of levopimaric acid from pine gum (under new and improved processing technology).

PROGRAM OF STATE EXPERIMENT STATIONS

State stations did not report work in this area.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Composition and Physical Properties of Pine Gum. Fundamental information on the chemical transformation of olefinic terpenes by hydroboration and subsequent reactions is being developed in contract research at Purdue

Research Foundation. A systematic study of the hydroboration of terpenes was undertaken to elucidate the mechanism of the reaction. Preliminary experiments were initiated with an alicyclic terpene, 3-carene. A study on the hydroboration of limonene will be initiated to obtain basic and fundamental information on the hydroboration of a diolefinic alicyclic terpene with an endocyclic and exocyclic olefinic moiety. (S4 1-112(C)).

B. New and Improved Industrial Products

1. Development of Intermediates for the Production of Resins, Plastics, and Plasticizers from Pine Gum and its Components. The preparation of chemical intermediates from naval stores products for use in industrial applications has continued. The esters and the corresponding mono and diepoxides of the esters of α-campholenyl alcohol [1-(2-hydroxyethyl)-2,2-3-trimethyl-3-cyclopentene and α-campholenic (2,2,3-trimethyl-3-cyclopentene-acetic acid) derived from α-pinene oxide], adipic, oleic, decanoic, and acetic acids have been prepared without difficulty. α-Campholenyl alcohol is easily obtainable from α-campholenaldehyde by aluminum isopropoxide or lithium aluminum hydride reduction. Esters from oleic, adipic, stearic, campholenic acids per se should make good plasticizers for PVC. With peracids, the corresponding mono and diepoxides are easily obtainable and should make good stabilizers and plasticizers for PVC. Since the epoxides react with acids to give a mixture consisting of alcohol (or ester) and ketone it seems unlikely that diepoxides will be useful for epoxy resin by the usual procedures. The epoxides, however, should undergo neutral or basic reactions to give amines, amino alcohols, glycols, and possibly polymers. A study of the chemistry of the epoxides of α-campholenyl alcohol will be completed. Evaluation of the esters and the mono and diepoxides of the esters for use as plasticizers and stabilizers will be continued. New work on forming copolymers of vinyl pinolate and vinyl chloride and vinyl acetate and study of the preparation and reaction (stability) of 2,2-dimethyl-1,3-(2-hydroxyethyl)-cyclobutane will be started. (S5 2-38).

Additional work prior to termination of the project (S5 2-40) on production of reactive chemical intermediates from turpentine by reaction with low molecular weight reagents indicated that the mixed terpenyl chlorides formed by chlorination of pinenes with hypochlorites could be used to alkylate primary amines such as butyl amine. On the basis of results from this terminated research project, the terpene-dienophile reactions have been selected as the most promising for addition of valuable functional groups to terpenes. In initial studies of the reaction of terpenes with dienophiles the separation and proof of structure of four acrylonitrile adducts, two fumaronitrile adducts, and the

tetracyanoethylene adduct of α-terpinene have been completed. The mixed acrolein adduct of α-terpinene, which can be prepared in high yield, was converted to a secondary amine by reductive ammonolysis with n-butyl amine. Successful reductive ammonolysis of α-terpinene opens the way for the production of a unique series of secondary amines for evaluation in various end uses. Separation and characterization of the α-terpinene Diels-Alder adducts will be completed as rapidly as possible and emphasis shifted to conversion of the primary products to amines and other derivatives. Methods for making similar products directly from dienophiles and pinenes or limonene will be sought. (3.1 man-years per year). (S5 2-40; S5 2-48).

2. Addition of Chemicals to Rosin Acids with Emphasis on Photochemical Methods to Produce Chemicals Useful in Manufacturing Surface Active Agents, Textiles, Paper and Plastics. The utilization of photosensitized-oxidized pine gum (POPG) as a cheap source of free radicals has been successfully demonstrated in a variety of applications and should help stimulate industrial interest in this product. A process for the preparation of POPG has been worked out in detail. Information as to the properties of POPG has been developed and is of considerable importance in the evaluation of POPG for specific industrial applications. Evaluation of POPG-diepoxide as metal salts as stabilizers for poly-(vinyl chloride) will be carried out. Work on the photosensitized reaction between levopimaric acid and sulfur will be completed. (S5 2-47).

3. Conversion of Turpentine and Rosin Acids into New Polymers, Protective Coatings and Resins. Research on the preparation of polyfunctional compounds from rosin, resin acids and derivatives by formaldehyde addition is being completed. The adduct of levopimaric acid and formaldehyde and the diol and other derived compounds are readily obtained from pine gum. Since the turpentine does not appear to be affected and the residual rosin should be usable as formaldehyde modified rosin directly or admixed with processed rosin, the present reaction offers a series of new products available without appreciable loss or degradation of saleable byproducts already known to the users of products from pine gum. It should be possible to find uses for methylolated resin acid mixtures and rosin as intermediates for new resins, polyurethanes, etc. (S5 2-43).

The development of a two-stage process for the preparation of rosin-based polyesters permits the preparation of low acid number products having greatly improved resistance to solvent and alkali. The discovery that heat polymerized rosin can be used in the preparation of high quality polyesters offers the possibility of preparing these products from higher concentrations of rosin and lower concentration of the more expensive dienophiles. The heat polymerized rosin should have a paler color and better color stability than ordinary rosin. The determination of the

stereochemistry of the Diels-Alder adducts of rosin used in this work was of assistance in developing methods for large scale separation of these products. Work on preparation of polyesters from rosin will be continued with special emphasis on use of thermally polymerized rosin as one of the dibasic acids. (S5 2-42).

Studies of the polymerization of terpene derivatives from pine gum have been made in contract research at the University of Arizona. One of the octadienes derived from pine gum copolymerizes with ethylene and propylene to give an interesting polymer. The functionality introduced via the octadiene may permit crosslinking or vulcanization of the polymer. A large chemical company is evaluating the terpolymer. The experimental work under this contract is nearing completion. Basic information has been obtained concerning the relative rates of polymerization of diverse monomers derived from agricultural products and of the general value of the homopolymers and copolymers obtained. (S4 1-89(C)).

Contract research on the application of the oxo and related reactions to terpenes and resin acids to produce alcohols, aldehyde, and acids is being carried out at the University of Cincinnati. Rates of reaction of several terpenes in the oxo reaction have been determined. Effects of solvent and temperature have been explored. In general, α-pinene and limonene react more readily than α-terpinene and myrcene. Mixtures of products are obtained in all cases. Progress has been made on separation and characterization of the products and tentative structures have been assigned to a few individual products. α-Pinene and limonene yield similar mixtures. Hydrogenation occurs along with hydroformylation. The results to date go far toward providing a basis for selecting one terpene for more intensive study and toward defining the course of the oxo reaction with terpenes. They also demonstrate the need for special conditions such as use of terpene-cobalthydrocarbonyl complexes if a double bond is to be retained or diols prepared. Future research will be on the investigation of the reaction of $HCo(CO)_4$ with terpenes in the absence of CO and H_2 and on other approaches toward getting unsaturated monofunctional products. (S5 2-45(C)).

Synthesis of terpene alcohols and glycols for use in the production of new and useful terpene derived polymers is being carried out in contract research at Cornell University. Screening reactions of α-pinene, limonene, camphene, α-terpinene, and myrcene with formaldehyde under thermal and acid catalyzed conditions have been carried out. Under thermal conditions α-pinene gives relatively high yields but complex mixtures. Camphene yields a major product in fair yield. Limonene also shows promise. Acid catalysis favors ester formation. Some of the products have been tentatively identified and others partially characterized. (S5 2-46(C)).

Research has continued on the development of a method for the determination of rosin and rosin derivatives in protective coatings in cooperation with the Pulp Chemicals Association. The Association supports a Fellowship for the research. Studies aimed at obtaining a gas chromatographic fingerprinting of the oil portion of tall oil modified alkyds have resulted in the discovery of a liquid phase which displays a remarkably good selectivity for the resin acids. The liquid phase of choice for GLC analysis of resin acid mixtures is Versamide 900 except where analysis for levopimaric acid is required. The fractionation and subsequent analysis of tall oil fatty acids containing rosin and rosin maleic adduct must be modified to include a means for determining small amounts of rosin in the adduct-containing fraction. (S5 2-39).

C. New and Improved Processing Technology

1. Processing Investigations to Produce Naval Stores Products of Improved Quality at Lower Costs. Research on the development of a process for the isolation of levopimaric acid from pine gum is being completed. Satisfactory processes have been developed for the isolation from crude pine oleoresin of levopimaric acid in the form of 2-amino-2-methyl-1-propanol salt products whose contents of levopimaric acid salt ranged up to 85%. These resin acid mixtures are of interest to the naval stores industry since they can be obtained more easily and more economically than pure materials. (S5 2-41).

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Chemical Composition and Physical Properties

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Schuller, Walter H., Minor, Jacob C., and Lawrence, Ray V. 1964. Photosensitized oxidation of pine gum to yield peroxides. Ind. Eng. Chem., Prod. Res. Develop. 3, pp. 97-100.

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McConnell, Nealy C. 1963. Operating instructions for cleaning and steam distillation of pine gum. U. S. Dept. Agr., Agr. Res. Serv., Sou. Util. Res. and Dev. Div., 3 pp.
Summers, H. B., Lloyd, W. D., and Hedrick, G. W. 1963. Isolation of resin acid mixtures rich in levopimaric acid from pine gum. I&EC Prod. Res. Develop. 2, pp. 173-177.

II. MAPLE SAP AND SIRUP - PROCESSING AND PRODUCTS
Eastern Utilization Research and Development Division

Problem. The extensive unused stands of sugar maple trees are largely located on land that is of marginal value to agriculture, areas commonly devoted to small-scale dairy farming. Since only a small percent of the available sugar maple trees are presently tapped for sirup, and we are importing some 50% of the sirup consumed in the United States, untapped sugar maples represent a good potential source of increased cash income for farmers in these areas. Based largely on recent research carried out in the Department and the State Experiment Stations, the methods of collecting and processing sap into sirup are being streamlined with resulting greatly increased efficiency and resulting greater hourly return to the sirup producer for his labor. The advent of tube collection of sap and the central evaporator plant promise to still further reduce the number of man-hours required to produce a gallon of finished sirup. Under proper conditions, maple sirup can be a seasonal crop of per acre value equal to or exceeding that of other farm products. While the results of previous research, such as establishing the great importance of sanitary collection of sap, have contributed to "modernization" of the industry, much more information is needed so that all operations for the production of high-quality maple sirup and other maple products can be conducted in a predictable, efficient manner. Not only can the low income farms be greatly benefited, but the existing maple industry in 14 states can be put on a higher economic plane and modernized to be made competitive with other crop and livestock farming to bring about an improved land use.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing program involving chemists, biochemists and microbiologists. These scientists are engaged in both basic and applied research in investigations concerned with the problems of improving sap handling and processing, producing high-quality maple sirup, and developing new outlets for all maple products while lowering the cost of the product. This work is conducted at Wyndmoor, Pa.

The Federal scientific effort devoted to research in this area totals 5.3 professional man-years. Of this number 2.6 are devoted to study of the chemical composition and physical properties of maple sap and sirup, 1.2 to microbiology of maple products and 1.5 to new and improved food products and processing technology.

In the research work cooperation is maintained with personnel of the Federal Extension Service in maple-producing states and with Cornell University.

PROGRAM OF STATE AGRICULTURAL EXPERIMENT STATIONS

A small research program on maple sap and sirup is in progress. Factors affecting the periodic sap flow in sugar maple are being studied by use of labeled isotopes. Effects of taphole treatment and collection methods are also being evaluated. Since the entry of the central evaporator into maple sirup operations, a study concerned with the economic feasibility of central evaporator processing has been completed. A good quality product may be obtained and analysis indicates a good potential for central processing.

Research on maple products production is currently concerned with sap flow, sap collection and sap dumping in systems using plastic tubing. Further investigation of the various sirup making operations and their effect on sirup quality is being pursued.

Some attention is being directed toward marketing systems for maple products and study of the potential demand for maple products in outlets located in heavily populated areas.

The number of professional man-years devoted to maple products utilization is 0.8.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

Investigations on maple sap and sirup to obtain information on which to base improved processing techniques for making better maple products at lower cost are being carried out in three different areas: (1) Formation of sugar sand in maple sirup, (2) Composition of maple flavor, and (3) Fermentation studies. A fourth study, storage of maple sap, will be undertaken through contract research as soon as a contract can be negotiated with a suitable processor.

A. Processing

1. Maple sugar sand formation. Studies in this area have been carried out through a research contract with the Ohio Agricultural Experiment Station at Wooster. The experimental work under the contract has been completed and will be terminated on receipt of the final report, which will be published as an Ohio Agricultural Extension Bulletin. Statistical analysis of the data shows: (1) A high correlation between sugar sand formation and calcium ion concentration of the sap, (2) Sugar sand formation is related to elevation and aspect (north, south, east or west exposure) of the sugar bush, i.e., sugar bushes at high elevation and southern exposure produce most sugar sand, whereas low elevation and

western exposure produce least amounts of sugar sand, (3) High precipitation in the spring favors sand formation and (4) Sugar sand formation tends to increase as sap flow season progresses.

The information obtained in this study dealing with the factors responsible for sugar sand formation and its character should be of considerable value in devising improved processes for making maple sirup. The study has also generated great interest in maple in Ohio as one of the natural resources of the State.

B. Composition Studies

1. Composition of maple flavor. The chemical nature of the maple flavor constituents that have been identified so far (vanillin, coumarin, syringaldehyde, coniferyl aldehyde, dihydroconiferyl alcohol and 2,6-dimethoxybenzoquinone) suggests their possible formation from soluble lignin fractions. Additional evidence was obtained to support this concept in that vanillin was produced by oxidation of ether-precipitated ligneous material from sample sap.

Since maple sirup is prized because of its characteristic flavor, additional information on the individual components of its flavor and of the mechanism of its formation from precursors in the sap will be of great value in preparing of maple products of improved quality. This work will be continued along present lines. Studies will also be continued on isolating and characterizing flavor precursors in the sap. It is also of considerable importance to develop specific methods for measuring formaldehyde in sap. Use of non-specific methods which would measure carbonyl groups (sugar breakdown products) as formaldehyde might give erroneously high values that could exceed limits of values set by the Food and Drug Administration. These limits were set by F.D.A. because of the use of paraformaldehyde as a tap hole sterilant.

C. Fermentation Studies

1. Production of acceptable maple sirup from buddy sap. Production of acceptable sirup from buddy sap would enable sap producers and processors to eliminate or reduce economic losses from this factor. The use of paraformaldehyde pellets in tap holes has extended sap flow into warm weather when buddy sap can be expected, and the possibility that large amounts of buddy sap will be collected at central evaporator plants places increased significance on developing procedures for converting buddy sap into an acceptable product.

Previous investigation has shown that controlled fermentation of buddy sap with the organism Pseudomonas geniculata removes the buddy flavor principle. Progress has been made in applying the procedure to buddy

maple sirup. Fermentation of sirup diluted with about three volumes of water eliminated or markedly reduced the disagreeable flavor and odor of the buddy sirup. Studies on the organisms that produce slime or gums in buddy sap should develop information that would be useful in devising methods that will reduce or eliminate their effect on the sirup.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Composition

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Underwood, J. C. 1963. Quick test for "buddy" flavor in maple sirup. U. S. Agricultural Research Service, ARS 73-42, 4 pp.

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Willits, C. O. and Stinson, E. E. 1963. Methods for the determination of carboxyl groups. In "Handbook of Analytical Chemistry," edited by L. Meites, Sec. 12-69 to 12-84, McGraw-Hill, New York.

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III. RANGE SEEDING, ESTABLISHMENT, AND MANAGEMENT AND VARIETY EVALUATION ON FOREST RANGES
Crops Research Division

Problem. Grazing lands of the United States occupy approximately 1,000 million acres as compared to 350 million acres of all harvested crops. It has been estimated that more than half of all the nutrients consumed by domestic livestock are provided by pastures and ranges. Improved grasslands are also essential to soil and water conservation. Information must be obtained on reliable, practical procedures for grassland management. Some of the major areas of research needing attention are concerned with seeding and establishment, including basic and applied physiological studies on the responses of pasture and range species and mixtures for different environments and management practices.

USDA PROGRAM

The Department has a continuing long-term program involving agronomists, plant physiologists, range conservationists and chemists engaged in basic and applied research on the management and improvement of grazing lands. All work is cooperative with the respective states and with the U. S. Forest Service in areas where grazing is integrated with National Forests.

The Federal scientific effort devoted to research in this area totals 2.5 professional man-years.

P.L. 480 projects in Israel relate to "Establishment and Maintenance of Seeded Dryland Range under Semiarid Conditions" and "Developmental Physiology of Perennial Pasture Grasses." Reports of another project, "Germination of the Seeds of Desert Plants," will be made available to ARS by FS.

PROGRAM OF STATE EXPERIMENT STATIONS

In recent years emphasis has been directed toward basic studies involving the understanding of principles, although surveys and other forms of applied research continue to be important. Vegetation re-establishment studies on the better range and pasture lands are an important part of the research program. Species evaluation, seeding techniques, and cultural practices are studied in an overall attempt to increase the productivity of these areas. Progress requires the combined efforts of agronomists, plant physiologists, climatologists, biochemists and range ecologists. Because of the great diversity of problems encompassed in this research, scientists work together through the mechanism of regional research projects such as: W-16 (Economics of rangelands), W-25 (Improvement of rangelands), W-34 (Range livestock nutrition) and

W-48 (Weather environment).

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Seeding and Establishment

1. Blue grama development influenced by seeding date and asphalt mulch. Late planted blue grama developed more rapidly than earlier planted blue grams in the extremely favorable 1962 season, and the advantage carried over through 1963 at the Central Plains Experimental Range near Fort Collins, Colorado. Early 1962 planting under an asphalt mulch, averaged 339 pounds/acre oven-dry herbage, whereas late 1962 plantings average 1,101 pounds in 1963. Without an asphalt mulch early 1962 seedings averaged 343 pounds/acre, and late 1962 seedings averaged 996 pounds/acre in 1963. All seedings were under favorable conditions with seedling emergence within 5 days. Plants from early 1962 seedings failed to tiller or produce seedheads in 1962 while the later seedings tillered and flowered profusely.

2. Herbicides effective in seedbed preparation. Dalapon plus 2,4-D destroys competing vegetation and conserves moisture for rehabilitation of abandoned cropland in the Central Plains. In comparisons of mechanical and chemical fallow at the Central Plains Experimental Range near Fort Collins, Colorado, dalapon at 10 pounds/acre plus 2,4-D at 1 pound/acre applied in April or May reduced yields of live herbage in August from 710 pounds/acre on control plots to 1 pound. Moisture in the top 30 inches of soil increased from 5.9 in control plots to 7.9 percent in treated plots, and in the top 12 inches from 7.0 to 9.2 percent. In contrast, tillage in April or May resulted in yields of live herbage in August of 369 pounds and moisture of 7.4 and 8.4 percent in the top 30 and 12 inches of soil, respectively. Dalapon plus 2,4-D leaves the dead vegetation on the ground to protect the soil from blowing and provides shade for fall seeded grasses.

3. Herbicides control cheatgrass: aid reseeding. Studies at Reno, Nev., demonstrated that atrazine and paraquat effectively control cheatgrass and provide an environment favorable for establishment of desirable perennial forage grasses. One pound atrazine/acre reduced yields of cheat ranging from 980 to 1,646 pounds at four locations to a range of zero to 307 pounds. Mustard was also controlled, but not Russian-thistle. Spring applications of 2, 1, .5, and .06 pounds paraquat/acre, with .1 percent x-77, reduced cheatgrass yields the same season 92, 85, 77,

and 31 percent, respectively. Mustard was not controlled. Seedlings of intermediate and crested wheatgrasses on areas treated with .5 pound paraquat/acre were 4 and 14 times as numerous, respectively, as on check plots infested with cheatgrass. Pubescent wheatgrass, spring seeded on land treated with 1.4 pounds paraquat/acre, yielded 1,600 pounds forage/acre the following year. A comparable seeding without paraquat yielded 48 pounds/acre. These studies are cooperative with Crops Protection Research Branch.

4. Forage grasses successful in vegetating southern California fuel breaks. Chaparral sites in southern California have supported destructive fires, and left large areas exposed to erosion by water. Studies in the Angeles, San Bernardino and Cleveland National Forests, at elevations of 1,600 to 5,600 feet have demonstrated the superiority of forage grasses as cover for fuel breaks. Of many grasses tested, pubescent wheatgrass A-1488, and tall wheatgrass A-1876 were most successful. Good results were also obtained from other strains of pubescent wheatgrass and with intermediate wheatgrass, Hardinggrass, nodding needlegrass, Lomas grass (a selection of blue wildrye), and Sherman big bluegrass. Tall wheatgrass, varieties Alkar and S-64, were poor.

5. Herbicides release forage on shinnery oak-infested ranges. Studies in western Oklahoma by personnel stationed at Woodward have shown that silvex controls shinnery oak and results in substantial increases in forage production. The most effective rate and time is one-fourth pound active ingredient applied in a water-oil emulsion about June 1. A single spraying kills about 30 percent of the shinnery,--spraying in two successive years about 55 percent and in three successive years 80 to 95 percent. Forage yield following spraying in two successive years increased from 992 pounds/acre on unsprayed plots to 2,139 pounds. Additional single sprayings each 5 to 7 years are expected to adequately suppress shinnery oak; 2,4,5-T at one-fourth pound/acre was only slightly less effective than silvex. The research is cooperative with Crops Protection Research Branch.

6. Mesquite invasion major problem in Southwest. The invasion of mesquite at a rate of about 1 percent/year, with the associated disappearance of good forage grasses and the formation of low dunes on sandy soils is a major threat to the livestock industry of the Southwest. Aerial spraying offers greatest promise of control even though the brush is fairly resistant and repeat spraying is necessary. Studies on the Jornada in southern New Mexico indicate that fair control can be obtained by two sprayings in different years of one-half pound 2,4,5-T/acre, in a diesel oil mix with water at 1:7. Single sprayings have generally been unsatisfactory. Spraying in 1958 and 1959 killed 32.2 percent of the plants; 1958 and 1960, 23 percent; 1958 and 1961, 37.3 percent;

1959 and 1961, 49.2 percent; and 1960 and 1961, 52.0 percent. Although outright kills are not high, most other plants are seriously damaged, and grass response is noticeable. In 1963, mesa dropseed yielded 82.5 pounds air-dry herbage on plots sprayed in 1958 and 1961, while adjacent unsprayed areas yielded 30.8 pounds/acre.

7. Brush encroachment studied on semi-desert grassland range. Studies based on periodic surveys including records extending back to General Land Office Survey Notes of 1858, have shown that good grass, then present on over 90 percent of the Jornada Experimental Range in southern New Mexico, now occupies less than 25 percent. During the same period mesquite has increased from 6,266 acres to over 66,000 acres, more than half the increase occurring since the survey of 1928. Creosotebush has increased from 644 acres in 1858 to 12,388 acres in 1963. Tarbush increased to 10,626 acres in 1928. Since then it appears to have invaded some heavy soils and to have given way on lighter soils to creosotebush. Seed dispersal from scattered stands of brush, accompanied by heavy grazing and periodic droughts, appear to be the major factors responsible for the spread of brush. Brush invasion on millions of acres of semi-desert grassland in the Southwest makes this the most serious problem ever faced by ranchers in that area.

B. Management

1. Sheep and steer combination grazing beneficial. Two stocking rates were used in a test at Beltsville, Md. Available forage was maintained at 500 pounds/acre for the high stocking rate pastures and 1,000 pounds/acre for the medium stocking rate pastures. Sheep and steer grazing in the same pastures were beneficial to one another. Daily gains for sheep with steers were greater than for sheep alone, and steers with sheep gained at a slightly faster rate than steers alone. An average of two tons per acre of forage was consumed at both stocking rates. The high stocking rate pastures produced an average of 236 steer unit days/acre, whereas the medium stocking rate pastures produced 217 steer days/acre.

2. X-ray spectrography shows promise. In cooperation with scientists at the U. S. Plant, Soil and Nutrition Laboratory, Ithaca, N. Y., an X-ray spectrographic technique has been developed for rapid determination of chromic oxide in feces samples. This method requires minimum sample preparation. Data has correlated well with chemical analysis in as many as 120 samples.

3. Water stress alters RNA. Research at Gainesville, Fla., has shown that basic cellular building blocks, the RNA (ribonucleic acid), which accumulated in plants under water stress, is unlike that found in plants grown without water stress. Chemical tests show that the large

composition differences are located in the small RNA cell fraction and can account for observed growth differences resulting from water stress.

4. Basic steps of non-protein nitrogen metabolism in plants determined. In India, work on a P.L. 480 project has shown that the ornithine cycle is operative in higher plants. This cycle is important in the metabolism of essential amino acids, and may prove useful in elucidating the complete plant growth process.

5. Russian wildrye provides excellent season-long grazing. Studies at Mandan, N. D., demonstrated that Russian wildrye, generally regarded as a companion of crested wheatgrass for early-season grazing deferment of native range, was capable of high production when grazed season-long. When Russian wildrye pasture was grazed 150 days from May 6 to October 3, at the rate of 2 acres/head, steers gained 280.9 pounds/head. Native pasture grazed moderately provided 140 days grazing at 5.75 acres/head and yielded gains of 273.4 pounds/head. Gains on Russian wildrye were 140.4 pounds/acre, and on native range 47.5 pounds. A rotation system with spring grazing on crested wheatgrass, summer on native range, and fall on Russian wildrye yielded gains of 75.2 pounds/acre and 281.9 pounds/head.

6. Fertilizer is key to productive range. Studies at Mandan, N. D., showed the important role of nitrogen fertilizer in maintaining high productivity from crested wheatgrass on native range pastures. In an 8-year study unfertilized crested wheatgrass declined about 50 percent in productivity while pastures receiving 40 pounds N/acre either did not decline or the decline was less than 20 percent. Renovation of native range was also more effectively accomplished by annual application of 30 pounds N/acre than by several seasons of complete rest from grazing use.

7. Germinating seeds undergo metabolic changes. In studies at Pullman, Wash., with germinating seeds of Nordan crested wheatgrass, a total of 19 phosphate compounds was separated by a formic acid and ammonium formate gradient. Among these, hexose phosphate, uridine diphosphate, and a number of other organic phosphate compounds not detectable in dormant seeds were synthesized within 24 hours after uptake of water began. Concentrations of these compounds continued to increase during 72 hours of germination. Inorganic phosphate decreased 50 percent during the first 24 hours of germination.

8. Forage production related to growth of juniper and sagebrush. The relative widths of annual rings in juniper and sagebrush may be useful in estimating forage production on arid rangelands. Herbage production

at Burns, Oreg., yielded the following correlations with annual ring measurements from juniper and sagebrush, respectively, from the same area: sprayed native range, .87** and .32; big bluegrass, .69* and .61; bluebunch wheatgrass, .59 and .71*; and crested wheatgrass, .52 and .78**. (* = significant at 5 percent level; ** at 1 percent level). The analyses were made at Fort Collins, Colo, with the collaboration of the Laboratory of Tree Ring Research at the University of Arizona.

9. Flood meadows respond differentially to time of nitrogen fertilization. Studies at Burns, Oreg., indicate that peak N concentrations are reached within one week after applications of 100 pounds N/acre to meadows made May 22 to July 3. Uptake could be detected within two days after application. Early-season fertilization yielded greatest increases in N content of herbage, but decline in N content of herbage was also hastened as compared with later fertilization. When grazing was allowed in spring until May 1, subsequent hay yields were reduced as much on fertilized as on unfertilized meadows.

10. Cheatgrass aggressive on fertilized range. When ammonium sulfate was applied to bluebunch wheatgrass range near Pullman, Wash., the annual weedy invader, cheatgrass, alone was benefited. Without fertilization bluebunch wheatgrass increased in yield from 560 to 1,200 pounds per acre when competing cheatgrass was removed. When 80 pounds ammonium sulfate/acre was applied, removing the cheat increased yields from 900 to 1,500 pounds/acre. When plots containing both grasses were given amonium nitrate for N, calcium sulfate for S, or both, bluebunch wheatgrass failed to respond to treatment. Cheatgrass failed to respond to N or S alone, but increased from 290 pounds/acre to 1,900 pounds/acre when given both N and S. On good condition range, bluebunch wheatgrass represented 23 percent of the cover on nonfertilized plots and 8 percent on plots receiving 80 pounds N in ammonium sulfate for 3 years. On poor condition range comparable values were 13 and 4 percent.

11. Fertilizer changes vegetation and microclimate. Nitrogen fertilization of native range increased western wheatgrass and needle-and-thread, and reduced blue grama, altering basal density and soil temperatures, according to studies at Mandan, N. C.

12. Seeded grasses respond to nitrogen on California rangelands. In the mountains of northeastern California at 11 to 30-inch precipitation, seeded grasses deplete soil of N in 3 or 4 years. Annual applications of 60 pounds N/acre gave fair to outstanding increases in yield, depending on available moisture. In the moderately favorable 1962 season, intermediate wheatgrass seeded in 1955, (average of 5 varieties) yielded 1,655 pounds when given 60 pounds N/acre as compared with 970 pounds without N. In the very favorable 1963 season, comparable values were

7,000 and 1,647 pounds/acre, respectively. In 1962 pubescent wheatgrass seeded in 1955 (average of 4 varieties) yielded 1,144 pounds when given 60 pounds N/acre and 577 pounds without N. In 1963 comparable values were 6,345 and 1,924, respectively. Seven species of wheatgrasses represented by 20 strains, in 1963 averaged 5,448 pounds per acre when given 60 pounds N/acre and 1,543 pounds/acre without N.

13. Paraquat preserves protein in range grasses. Studies at Burns, Oreg., showed that grasses sprayed with paraquat at anthesis retained protein during the following 4 months. Non-treated grasses experienced the well-known decline in protein. Plots of bluebunch wheatgrass were sprayed at anthesis (June 22) with .8 pound paraquat cation/acre, with X-77, and sampled the same day and 7/17, 8/20, and 10/23. The crude protein found in untreated and treated forage, respectively, for the 4 dates, was as follows: 9.4 and 9.1 percent; 7.4 and 9.0 percent; 5.8 and 9.4 percent; and 4.9 and 8.8 percent. There was a rapid loss of carotene in treated forage relative to untreated, and a gradual decline in calcium. Preliminary data suggest that paraquat prevented the characteristic decline in digestibility associated with maturing of grasses. Plots treated in 1962 did not suffer significant yield reduction in 1963.

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IV. WEED AND BRUSH CONTROL ON FOREST AND RELATED RANGES
Crops Research Division

Problem. Losses to weeds and brush on grazing lands and present costs of their control total almost $1 billion. Brush infests 320 million acres of range and pasture land in the United States. In Texas alone, it is estimated that brush infests 88 million acres of the 107 million acres of grazing land. In addition, millions of acres are infested with weed grasses and other herbaceous weeds that displace valuable forage species, reduce production and quality of forage, cause poisoning of and physical injury to livestock and reduce the quality of animal products. Also, weeds frequently cause failures in establishment of new seedings. The losses caused by weeds and brush must be reduced by expanding research to find more effective chemical, biological, mechanical, cultural and combination methods of weed control. Expansion of fundamental studies on the physiological and biochemical responses of weeds and crops to herbicides can provide information on the relation between molecular structure of herbicides and their modes of entrance, movement, behavior, metabolism, persistence, and fate in plants and soils. Improved effectiveness of herbicides requires more information on the effects of environment, soil, plant structure, and method and time of application on plant responses. Research on the integration of herbicide and herbicide-cultural methods of weed control into management systems should be expanded.

USDA AND COOPERATIVE PROGRAM

The U. S. Department of Agriculture has a continuing long-term program in both basic studies and the application of known principles to the solution of weed problems. Although research is being conducted which has general application in all areas of weed control such as studies on herbicide evaluation, on the mode of action of herbicides, on fundamental principles of the role of surfactants in herbicidal effectiveness, and on the behavior and detoxification of herbicides in soils, only the research directly related to control of weeds and brush on grazing lands are included in this report. The latter includes studies of the life histories and growth patterns of individual weeds, principles of competition among weeds and forage plants and the use of cultural methods, biological agents and herbicides for their control. Comprehensive studies are made to develop principles, practices and methods of using herbicides and other weed control techniques in solving regional and national weed and brush problems in grazing lands.

Research on the control of weeds is conducted cooperatively with State Agricultural Experiment Stations and with Federal agencies, including the Bureau of Reclamation and Bureau of Land Management, Department of the Interior, Forest Service of the Department, United States Army Corps of Engineers, Department of Defense, and Plant Pest Control Division of the

Department. Industrial companies cooperate in furnishing experimental chemicals, equipment, and funds essential to rapid progress in weed control investigations.

The Federal scientific effort devoted to weed and brush control research on rangelands in or near forested areas is 23.0 professional man-years and 2.0 professional man-years on control of phreatophytes.

PROGRAM OF STATE EXPERIMENT STATIONS

State experiment stations are conducting basic and applied research in weed control. These studies involve evaluation of selective herbicidal properties of new chemicals, the nature, behavior, and effect of herbicides on their degradation products in and on plants and plant products; the mechanism of herbicidal action; influence of climate, plant morphology and soil characteristics on the effectiveness of herbicides in selectively controlling weeds and on their persistence in plant tissue.

Weed life cycles and growth habits are being studied under different environments to determine the most susceptible stage of vulnerability to herbicides and other control measures. Other aspects that are currently being investigated are: competition between weeds and desired plant successions following control measures including replacement vegetation and management practices. Relation between weeds and biological control organism that attack them in different environment is being studied on a limited scale.

Much of the research in weed control is being done via regional projects. The USDA cooperates on much of this research activity.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Weed Investigations - Grazing Lands

1. Poisonous and Other Herbaceous Weeds. Paraquat plus surfactant gave excellent early control of downy brome on plots at 5 locations in Nevada and Northern California, although late in the growing season some regrowth occurred and there was only fair control with 0.5 lb/A of paraquat. Despite regrowth, average yield reductions of downy brome at the end of the growing season, was 77% with 0.5 lb/A, and 31% with 0.06 lb/A compared to the check. Paraquat at 0.5 lb/A with X-77 and Tergitol TMN surfactants at 0.1% reduced yield of downy brome in one field trial over 90%, with 15 other surfactants yield was reduced from 73 to 86%, and with 5 others from 48 to 68%. Paraquat without surfactant reduced downy brome only 12%. There were 5 times as many intermediate wheatgrass seedlings where downy brome was killed by 0.5 lb/A of paraquat used in the spring just before planting as there were in the check (1.4 plants per foot of row). Crested

wheatgrass was increased from 0.2 plants to 2.8 plants. Second-year yields of pubescent wheatgrass were increased from 48 lb/A on check plots to over 1,600 lb/A where paraquat was used to control downy brome at planting time. Atrazine and isocil appeared to be the most promising herbicides for weed control in a chemical-fallow program on downy brome infested range areas in Nevada.

In Maryland, paraquat applied simultaneously with the planting operation at 0.5 to 1 lb/A showed promise for control of sward competition where forage species were drilled directly into the sod.

In Mississippi, good to excellent weed control and sod development of newly sprigged Coastal Bermudagrass in a heavy sandy loam resulted from preemergence treatments of 4 lb/A of simazine, 2 lb/A of 2,4-D, and various combinations of 1 and 2 lb/A of simazine plus 2,4-D. Almost as good were CIPC at 12 lb/A, 2,4-D at 1 lb/A, and trifluralin at 2 lb/A when incorporated in the soil. Untreated plots formed very little sod. Very poor sod developed in corn as a companion crop even with excellent weed control.

In Indiana, alfalfa yielded 1-1/2 T/A in the year of establishment when weeds were controlled by EPTC at 3 lb/A and DCPA at 6 lb/A applied preemergence followed by 1-1/2 lb/A of 2,4-DB applied early postemergence. By controlling weed grasses in the year of establishment of birdsfoot trefoil, higher yields of this forage were produced in successive years.

Placing EPTC in a band in the furrow at the time of seeding birdsfoot trefoil shows promise for controlling weeds at a reduced cost for chemicals in New York. Soil covered the herbicide to a depth of 2 inches. Effective weed control was obtained at 4 and 6 lb/A of EPTC in the band. Birdsfoot trefoil was not damaged significantly. In Maryland, trifluralin at 1 to 2 lb/A incorporated into the top 4 inches shows promise for controlling grasses in establishing legumes for forage. The safety margin needs further evaluation. Ethyl 1-hexamethylene imine carbothiolate appears to have about the same specificity and activity as EPTC for forage legume establishment.

In Idaho, fair topkill of bracken fern resulted from dicamba at 8 lb/A; dicamba at 6 lb/A plus 2,4-DP at 2 lb/A in combination; and 4-CPA plus 2,4-DP, each at 3 lb/A in combination. Picloram (4-amino-3,5,6-trichloropicolinic acid) at 2 to 6 lb/A gave excellent topkill of bracken fern.

The most effective herbicides on falsehellebore (Veratrum californicum) were propylene glycol butyl esters of 2,4-D and oleoyl 1,3-propylene diamine salt of 2,4-D. Falsehellebore cause "monkey-faced lambs" if injested by ewes during 12-14th days of pregnancy. The most effective date of treatment was June 26, or just before bud formation. Effective killing of plants was obtained with 2 lb/A of both herbicides. The effectiveness of the 2 lb.

rate was based on an examination of the dormant bulbs in late September. All bulbs examined were rotten.

Prometryne applied at 8 lb/A in September of 1962, to a stand of salt sage (Atriplex nuttalli) infested with halogeton prevented any halogeton establishment during the growing season of 1963. The salt sage plants on these plots measured approximately 1-1/2 times as tall as those on the control plots and twice the height of plants treated with TBA. Salt sage treated with 8 lb/A of prometryne responded with vigorous growth because of decreased stand of halogeton and because the treatment did not injure salt sage.

In Nebraska, the phenoxy herbicides had little effect on whorled milkweed as observed during the year of treatment whereas dicamba and picloram appeared to be effective. Also in Nebraska, dicamba appeared to be the most effective herbicide for control of musk thistle. It not only showed good contact activity and immediate kill but also appeared to have some preemergence activity at the 2 and 3 pound rate. Two,4-D and 2,4,5-T gave excellent control in the fall and good control at the early spring treatment date. Two annual treatments of 2,4-D or 2,4-D-2,4,5-T mixture applied in water or in water plus a surfactant were more effective than either material applied in diesel oil for control of perennial ragweed in Nebraska.

Because germination of sumpweed in the greenhouse and in the field extends over a long period of time, 2,4-D preemergence gave inadequate control, in Mississippi. Sumpweed was adequately controlled when plants, 6 to 12 inches tall, were treated with 1/2 and 1 lb/A of dicamba, 2,4-D, picloram, and 1 and 2 lb/A of 2,4-DB. It took only about one-half as much picloram as 2,4-D and dicamba for control of bitterweed.

In Missouri, early treatments of ironweed with 2 lb/A of 2,4-D ester were more effective than late treatment. Two,4-D was more effective than dicamba and dicamba more effective than 2,3,6-TBA. Mowing ironweed and spraying the regrowth with 2,4-D or fertilizing with nitrogen and spraying with 2,4-D were more effective for controlling ironweed than 2,4-D alone. Picloram at 1/2 lb/A or higher nearly eliminated top growth of ironweeds and was superior to 2,4-D. However, picloram was ineffective on coralberry at rates up to 1 lb/A.

Mowing Canada thistle after each grazing period during two seasons in Indiana, significantly reduced the weed as a competitive plant regardless of the initial weed density. These results are based on the high density and dry matter yield of alfalfa. Two,4-DB applied to Canada thistle in the early bud stage controlled this weed for the season. Picloram shows particular promise for control of Canada thistle in Washington, Montana and other states.

Mowing broomsedge at 1, 2, 3, and 4 week intervals for three seasons reduced stands 80, 60, 44, and 25%, respectively, in Mississippi. Nitrogen fertilization in addition to mowing of plots of broomsedge in which some Dallisgrass was growing resulted in 36% reduction in stand of broomsedge by the end of the season. Complete fertilizer in 1962 plus nitrogen alone in 1963, and mowing annually, resulted in closer grazing and reduction in stand of broomsedge and an increase in Dallisgrass. Most effective herbicide treatments on broomsedge were two applications of paraquat at 5 and 10 lb/A (92 and 99% control, respectively), but 10 lb/A almost eliminated first year Dallisgrass.

In Maryland, silvex was far superior for control of oxalis repens to either 2,4-DP or combinations of silvex with picloram, dicamba, and 2,3,6-TBA in greenhouse tests. In a field study, dicamba plus 2,4-D was far superior to silvex or 2,4,5-T for control of red sorrel (Rumex acetosella).

2. Brush Control

a. Physiological and Ecological Studies. In Arizona, foliage moisture content of one-seed juniper was lowest and least variable during May over a 4-year period and the greatest plant to plant variation occurred during the summer months. This may partly explain the wide variation in response of juniper treated with chlorophenoxy herbicides during the summer. Addition of water to the soil during the hot, dry months of May and June increased the effectiveness of foliage applications of an ester of 2,4-D on one-seed juniper.

In Texas, foliar applied butoxyethanol ester of 2,4,5-T was translocated farther from the point of application and in greater quantity by live oak and mesquite plants when applied with ammonium thiocyanate than when applied alone in a diesel oil-water carrier.

During studies with amitrole translocation, a rapid in vitro nonenzymatic inactivation of this compound was observed in mesquite seedling preparations in Arizona. Inactivation potential was positively correlated with leaf age, and increased in a basipetal direction in the stem, reaching a maximum of about 90% in the tap root. The fibrous branch roots had considerably less inactivating potential than did the tap root. Young mature leaves had a greater inactivating capacity than either newly emerged or old overwintering leaves. After inactivation, all material recording as amitrole was shown to be in the original molecular form, since removal of any possible amitrole metabolites by ion exchange did not alter the analysis.

In Texas, the effects of 2,4,5-T were studied on 3- to 14-day old mesquite seedlings. Concentrations of 1, 5, 10, and 20 ppm of 2,4,5-T arrested seedling elongation growth but did not prevent growth entirely. The hypo-

cotyl and root were thicker in the treated seedlings than in the controls. Cortex disruption was common immediately below the collar in the treated seedlings by the fifth day. The 2,4,5-T stimulated cell division in the cortex, pericycle, and cambium. Most cell division occurred immediately outside the phloem.

Stem and root transections and radial sections were cut on 5-month greenhouse mesquite plants in Texas. The structure of the stem was similar to that of a new stem on a larger tree. Stomata were present on the upper two-thirds of the stem. The root had a lower density of xylem vessels than did older plant roots.

Pricklypear pads were readily killed by 2,4,5-T formulations in diesel oil when applied to one surface, in Texas. The treated pads were held at 90°F in the greenhouse. Little injury occurred on the untreated pad of 2-pad segments when the other was killed by 2,4,5-T.

Growth chamber and greenhouse evaluation of picloram on mesquite seedlings were carried out with foliage applications ranging from 5 to 5,000 ppm and soil applications of from 1/25 to 5 lb/A in Arizona. Physiological responses were significantly greater than those resulting from 2,4,5-T and a positive correlation of herbicide concentration with plant damage existed with picloram. Treatment of seedlings with 2,4,5-T results in an overall injury which does not increase with increasing concentrations because of severe injury to the conductive tissue. This is apparently the reason why kill of mesquite by aerial spray cannot be further increased by 2,4,5-T rates exceeding 1/3 lb/A.

The number of shoots on the branches of mesquite at Benchley, Texas, increased 20 to 35% yearly. New shoot growth was initiated about March 18 and ended by April 20. One leaf was produced per node on new shoots. More than one leaf was produced per node on 1-year terminal nodes. Fewer than one was produced on the older nodes and succeedingly older wood. Floral racemes were produced acropetaly on new stems. Many had begun blooming by May 7. On older wood, flowering had begun by April 18. Also in Texas, most honey mesquite leaves produced 40 to 48 leaflets. Only a few trichomes were present. Cuticle began developing about April 18, resulting in layers 6 and 2 microns thick on the upper and lower surfaces, respectively. About 20,200 stomate per cm^2 were found on the upper leaf surface; about 10,500 were present on the lower surface.

Histological studies of velvet mesquite leaf cuticle development in Arizona have shown that naturally-growing seedlings and trees form an effective cuticle shortly following bud-break in the spring. Such development was independent of plant size and apparently not greatly affected by additional irrigation in the case of garden-cultured plants.

Seedlings grown in vermiculite and water with nutrient did not develop a significant cuticle in the greenhouse even after 8-1/2 months. When grown several months outdoors, they developed little or no more cuticle than in the greenhouse. Seedlings planted directly in the soil outdoors and allowed to reach an age of one year did develop a fairly thick cuticle. A portion of the leaves of a large tree which were allowed to mature inside a glass chamber formed a good cuticle about half the thickness of leaves just outside the chamber.

Further studies at Tucson, Arizona, of the mesquite leaflet by electron microscopy have disclosed interesting anatomical features. Perhaps the most significant being the presence of a double-layered vacuolar membrane or tonoplast in the sclerenchyma cells, exactly as has been shown to exist in the chloroplast membrane.

b. Control Studies. Spraying equipment consisting of a 33-foot, 3-section, hydraulically controlled boom mounted on a 3/4 ton, 4-wheel drive truck for experimental plots was developed in Texas, which permitted broadcast spraying of woody plants up to 15 feet tall.

At Woodward, Oklahoma, the optimum date of spraying for shinnery oak was determined as June 1. On this date, a single spraying will kill about 30% of the shinnery oak, 2 successive annual sprayings will kill about 55%, and 3 sprayings from 80 to 95%. Percentage kills from treatments 15 days before or 15 days after the optimum date were 10 to 15% lower and those one month earlier or one month later were only about 50%. If shinnery oak is injured by late frost, early drought, fire or insects, higher kills will result from spraying 2 to 4 weeks after the usual optimum date of spraying, providing growing conditions have allowed shinnery oak to put on new leaves and continue a rapid rate of growth. Even then, percentage killing of oak will usually be only 60 to 80% of optimum.

In Mississippi, 3 sprayings (2 in 1962 and 1 in 1963) of regrowth of Cherokee rose resulted in greatly reduced stands but not eradication by October 15, 1963. Percent stand reduction by 4 lb/A of 2,4,5-T, 2,4,5-T plus surfactant, 2,4-D, 2,4-D in diesel oil, TBA, TBA plus surfactant, dicamba, and dicamba plus surfactant, ranged from 87 to 98%. One year's results with picloram shows this herbicide is very promising for Cherokee rose control.

In Maryland, picloram shows promise for controlling multiflora rose (1 lb/100 gallons of water as a foliage wetting spray or 5 lb/A applied as pellets at the base of the hedge). Good top kills were obtained with the potassium salt of picloram applied to junipers and shrub live oak in Arizona.

A single application of pelleted fenuron was as effective as split applications onto shrub live oak at a total of 8 lb/A. A 5-foot grid application was slightly better than broadcast applications but strip applications were not. Burned over shrub live oak plots treated with 8 lb/A of fenuron in July 1961, produced an average of 1,526 pounds of oven dried lehmann lovegrass forage per acre in September 1963. Untreated plots averaged only 397 pounds per acre.

At Lincoln, Nebraska, after two full years from the date of last treatment with 2,4-D, there is still roughly 90% reduction of the buckbrush population while the plots treated with the 2,4-D-2,4,5-T mixture show roughly an 80% reduction. Plots mowed in 2 successive years had 37% less than that of the untreated plots.

Dicamba as a foliage application to persimmon in 4 lb/100 gallons of water in Missouri, was superior to 2,3,6-TBA at the same rate. Ground treatment of 16 lb/100 gallons of fenac was almost ineffective and inferior to 2,3,6-TBA.

In Nevada, 95 to 100% control of black sagebrush (Artemisia arbuscula) resulted from treatments with 2,4-D, 2,4,5-T, and silvex at 1, 2 and 3 lb/A applied on May 1, May 15, and June 1, 1962. Plots sprayed in 1962 produced an average of 340 lb/A of forage compared to a check yield of 204 lb/A the first year after treatment.

Dormant basal broadcast applications of 12 pounds of an ester of 2,4,5-T per 100 gallons of diesel oil on gambel oak sprouts gave a 32% plant kill and a 79% stem kill within 2 years in Arizona.

3. Phreatophytes

a. Physiological, Ecological, and Biochemical Studies. Techniques were developed at Los Lunas, New Mexico, for rapid and continuous production of saltcedar (Tamarix pentandra) plants for greenhouse and laboratory experiments. Stem cuttings 1/4 to 1/2 inch in diameter harvested at weekly intervals during the year were rooted and grown with about equal facility except for 90 percent dormancy of buds on cuttings harvested in October. Rooting compounds were deleterious to the production of roots and stems from cuttings. Vegetative growth from saltcedar cuttings was affected by photoperiod and these effects were different in September from those in February-March.

Germination of saltcedar seed was not significantly inhibited by concentrations of sodium, calcium, potassium or magnesium chloride at levels ranging from 200 to 4000 ppmw but was progressively reduced to about one-third

that of seed in distilled water by concentrations of chlorides ranging from 10,000 to 160,000 ppmw.

b. Control Studies. Aerial spray applications on saltcedar in Arizona and Texas showed an ester of silvex and 50-50 mixture of esters of 2,4-D and 2,4,5-T to be more effective than an amine salt of silvex. There seemed to be a considerable advantage for spraying early in the growing season. In ground spray applications both the amine and ester formulations of silvex gave better results than esters of 2,4-D or 2,4,5-T or any other chemical.

Basal and cut stump sprays of esters or oil-soluble amine formulations of silvex applied at 8 lb acid equivalent per hundred gallons of oil gave excellent kills of individual saltcedar trees with slightly better results from the ester formulation and on smaller trees and cut stumps. Results were equally good from applications in April or December.

In Montana single applications of picloram applied at bud stage at 1 and 2 lb/A eliminated 97 to 100 percent, respectively, of Canada thistle (Cirsium arvense). Single applications of dicamba at 2 and 5 lb/A gave 80 and 100 percent elimination, respectively, of Canada thistle. Both chemicals proved considerably more effective than 2,4-D for control of Canada thistle.

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